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Agricultural Memorandum No 872

Mapping of Areas Suitable for the Cultivation of Outdoor Bush Tomatoes

Summary

Following the introduction of hardy sub-Arctic varieties of dwarf tomato plants into Britain, the National Vegetable Research Station has been able to assess the limiting weather factors for profitable cultivation of this crop. In this paper these criteria are used to define the areas within England and Wales which are suitable for this enterprise.

1. Introduction

Although not a new crop in this country, dwarf tomato varieties such as Sleaford Abundance and Scotia have only been grown in a few isolated areas by growers willing to arrange either local distribution or a "pick your own" scheme.

It can now be shown that dwarf tomatoes could be grown on a scale large enough to interest commercial firms catering for the home market in processed tomatoes.

Due to the more marginal nature of our weather compared to that of say Italy from where a large quantity of canned tomatoes are imported, the cost incurred in producing a 400g (14 OZ) tin containing home grown tomatoes will lead to a retail price of around 19p as against 15p for the imported varieties (at 1979 prices).

On cost alone a home produced tin would not be competitive but it is hoped that a product of superior quality and flavour can be grown and sold successfully to the upper end of the domestic market. Consumer tests already carried out by one large canning firm have indicated the acceptability of the product to the general public.

2. Methods of Cultivation

Two methods were tested by the N.V.R.S. at a few sites in the Midlands and South of England. (Gray, 1979)

The first method was based on a growing season from the 15th May, when young plants were transplanted from a cold glass-house or Dutch light frame to the field, to the 30th September, which is near to the latest date a successful harvest could be obtained. Planting out before the 15th May would not be advisable in most areas due to the increasing probability of damage by frost.

The second method entailed the fluid sowing of pregerminated seeds directly into the field on the 1st of May with the crop being harvested around the 30th September.

From the point of view of cost, the dwarf varieties have several advantages over more conventionally grown glass-house tomatoes.

The dwarf tomato plant requires very little attention after planting because the side shoots which would have to be pinched out in the glass-house varieties are allowed to grow and produce trusses. The fruit sets on all the trusses around the

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same time and so fairly uniform development is assured up to harvest when only a small part of the yield is lost through being immature. The optimum fruit size at harvest is 35-40 mm in diameter.

3. Crop development and temperature

Two methods to relate crop development to temperature were tested during the growing season. These were 1) the use of the accumulation of day-degrees above a base of 10°C and

2) the use of the accumulation of Ontario Heat Units (OHU).

The latter method produced results much more consistent with those observed during the trials, with an accuracy in estimating the date of harvest of ± 5 days in 6 out of 8 occasions. (Gray, personal communication)

This method using OHU's has already been tested successfully on the development of maize.

The daily calculation of OHU's is made in two parts. The day term is defined by

$$H_D = 3.33\ (TMAX - 10.0) - 0.084\ (TMAX - 10.0)^2$$

and the night term

$$H_N = 1.8\ (TMIN - 4.4)$$

with the resulting Heat Unit = $(H_D + H_N)/2$

where TMAX is the daily maximum air temperature (°C) and TMIN is the night minimum air temperature (°C) (Hough, 1978). The day term is nearly linear between the base of 10°C up to 20°C and appears to be a simple representation of the effects of temperature on photosynthesis, and the night term probably defines the effect on respiration caused by the difference between air and soil temperatures.

For the first method of cultivation the accumulation of OHU's from the 15th May to the 30th September necessary for a yield of 37.5 tonnes per hectare (15 tons per acre) is 1932, and 2125 for a yield of 50 t/ha (20 t/a).

For the second method the units required are 2406 for 37.5 t/ha and 2599 for 50 t/ha. (Gray, unpublished)

4. Analysis of Data

Data were obtained for 44 daily reporting stations, mainly in the South, but with a few as far North as the Vale of York. (See fig 1). For each of these stations a mean daily temperature, (TMAX + TMIN)/2, and an OHU figure were calculated for both growing seasons forming mean seasonal temperatures and OHU totals for each year from 1959 to 1977. Details for each station including the 19-year means and totals are given in fig 2.

Using a routine supplied by the Numerical Algorithms Group (NAG 1977) a simple linear regression was fitted to the seasonal totals of Ontario Units and mean temperatures, some 836 pairs of data points, giving for the

1st May to 30 September period $OHU = 251.6(T) - 1184.9$ (1a)

or $T = (3.887 \times 10^{-3})\ OHU + 4.920$ (1b)

and for the 15th May to 30 September $OHU = 223.4(T) - 992.1$ (2a)

or $T = (4.384 \times 10^{-3})\ OHU + 4.732$ (2b)

where T is the mean daily temperature for the growing season, and OHU is the appropriate period total of heat units. In all cases the correlation coefficient was 0.99.

An attempt was then made, unsuccessfully, to relate the mean seasonal temperature to altitude and latitude using a multiple stepwise regression routine.

Although the results from this were not totally unreasonable, the resulting equation for the 15 May to 30 September period was

$$T = 26.82 - 0.004\ (HT) - 0.23\ (LAT)$$

where T is the mean temperature 15/5 to 30/9 °C

HT is the height of the station above sea level in metres

and LAT is the latitude of the station in degrees.

This gave a lapse rate of 0.4°C per 100 m with height
and 0.23°C per degree of latitude.

This lapse rate with height does not agree well with any of the previously published data consulted (eg. Green and Harding, 1979; Harding, 1979; Smith, 1976) and was therefore disregarded.

The possible causes for this disagreement include

1) the site to site characteristics and exposures could produce significant variations from the expected figure.

2) no allowance was made for the distance of the station from the sea, proximity to which would tend to slightly reduce the mean temperature.

3) the unequal geographical distribution of the stations chosen could bias the regression.

4) most of the sites chosen were at low altitudes, only five were over 100 m, again leading to a possible bias.

With reference to the first point it can be seen from the mean temperatures shown in fig 2 that the warmest site was at Oxford, although being 51.8° North and 63 m above sea level.

Further work could be done on this aspect, but for the present a lapse rate with height above sea level of 0.6°C per 100 metres has been chosen as being representative of previous research on the subject.

There is evidence which suggests the lapse rate is not constant throughout the growing period, with the rate being slightly greater during the months of July to September. (Smith, 1950; Smith, 1976)

This higher lapse rate of around 0.65°C/100 m could prove critical at higher altitudes as the crop approaches maturity, and should be borne in mind during the assessment of suitable sites.

Given the failure to establish a workable relationship with altitude and latitude, reference was made to M.A.F.F. Technical Bulletin 35 (Smith, 1976) to determine, for each agro-climatic area in the region under consideration, the mean temperatures during the growing seasons.

The accumulation of heat units, being dependent on temperature, is a major restraint on possible areas of cultivation, but other significant elements which should be considered are spring frost and soil temperature. Of these, frost proves to be the more limiting, but by its nature the more difficult to quantify. With the frequency and degree of frost being so dependent on the actual siting of a field, due to say the difference between a frost hollow and a south facing slope, only a rough guide can be given on the areas where the probability of frost is too great.

Typical values for central southern England are the 28th April for the mean date of the last air frost, with a standard deviation of 16 days. This gives a probability of 0.1 for an air frost after the 14th of May. (Beck, 1977) Late April was therefore taken as the latest acceptable mean date for the last air frost.

This limitation excludes all areas to the north of a line from the Wash to Mumbles Head and round to Aberystwyth and Dartmoor and Exmoor, with the exception of a small area around Liverpool. (fig 3)

Soil temperatures, at the planting depth of 25 mm, in excess of 10°C during early May are required for the successful development of the pregerminated seed, and in excess of 11.5°C for satisfactory radicle growth of the young plant. (Gray 1979)

Long term averages of 10 cm soil temperatures were not available, but by using the 30 cm values given in Bulletin 35, which would be generally lower than a 10 cm temperature during May, it was found that this did not provide a further limitation.

The mean air temperature for the period 15th May to 30th September cannot be obtained directly from the data published in the Bulletin. To overcome this the temperature data from the stations analysed were compared for both growing seasons. It was found that the shorter period was warmer by an average of 0.339°C with a standard deviation of 0.014°C. This provides a good estimate given the mean temperature for the period 1 May to 30 September.

Before undertaking the cultivation of dwarf tomatoes, the grower would want to ensure that the crop would have time to mature in the majority of years, and thereby reduce the risk of part or total loss of the crop. This level is taken as success in 9 years out of 10.

Ontario Units are distributed nearly normally about the mean with a standard deviation averaged over the 44 stations of 191 OHU's for the 1/5 to 30/9 period and 172 OHU's for the 15/5 to 30/9 period.

To ensure success 9 years in 10 the number of OHU's required from planting out to 37.5 t/ha will now have to be 1.282 standard deviations above the mean ie.

$1932 + (1.282 \times 172) = 2152$ OHU

Calculations for the target yields were done for planted and sown crops, table 1.

Table 1

Target yield (t/ha)	OHU	Equivalent Mean Temperature (from 1b & 2b)
(1) Planting (15/5 - 30/9)		
37.5	2152	14.166
50.0	2345	15.012
(2) Sowing (1/5 - 30/9)		
37.5	2650	15.220
50.0	2844	15.975

The lower mean temperatures are attained in many parts of the country but the chances of obtaining a mean temperature of 15.975 are remote even in the best of situations. Only during 1976 was the mean temperature close to this threshold.

A small difference was noted between the adjusted sea level temperatures contained in Bulletins 35 (fig 3) and those calculated for the stations. This difference was of the order of $\pm$ 0.3°C, being generally cooler during the 1959-77 period. A few stations were checked over both the 1941-70 and 1959-77 periods and this difference was verified.

Looking at a longer term analysis of mean temperatures it would appear that the 1941-70 summer period was one of the warmer ones since 1901.

Table 2. Mean Temperatures at Oxford

PERIOD	MAY	JUNE	JULY	AUG	SEPT	MAY - SEPT
1901-30	12.1	14.4	16.6	16.0	13.7	14.6°C
1911-40	12.2	14.8	16.7	16.5	14.0	14.8°C
1921-50	11.9	15.1	17.1	16.7	14.4	15.0°C
1931-60	12.0	15.3	17.1	16.9	14.4	15.1°C
1941-70	12.1	15.3	16.9	16.5	14.4	15.0°C

Similar figures are published for Eastbourne (Met Office, 1976).

Some idea of the more favourable growing conditions on the Continent is obtained from the mean temperature figures representative of Northern Italy during the period 1946-65

MAY	JUNE	JULY	AUG	SEPT	MAY - SEPT
18	21	24	24	21	21.5°C

There is, of course, no way of predicting whether the climate within the next 10 years or so will differ significantly from that in the recent past, but it should be borne in mind that what is already a marginal crop for this country, would be adversely affected by a return to the cooler conditions evident earlier this century.

5. Compilation of the maps

For each agroclimatic area the mean seasonal temperature was adjusted to mean sea level (fig 3) and back to the threshold values given in table 1. The resulting heights for each area were noted (fig 4) and indicate the altitude below which a successful crop should be obtained for the given yield for 9 years in 10.

To give a graphical representation of the data contained in figure 4, ordnance survey maps were examined to select the areas where the criteria are fulfilled.

The maps shown are, for 9 years in 10; planting to 37.5 t/ha (fig 5); planting to 50 t/ha (fig 6); sowing to 37.5 t/ha (fig 7); and for 8 years in 10, sowing to 37.5 t/ha (fig 8).

The last map shows the increase in the potential areas of cultivation if a smaller probability of success is accepted. This higher risk may possibly be offset by a more strict selection of a site.

Concluding Remarks

These maps, by their nature, can give only rough guidance; clearly not every valley or hill top is detailed.

Additionally some otherwise suitable areas will be disqualified for other reasons such as poor soil conditions, badly exposed sites, or the non-availability of a ready market for the product.

The marginal nature of this crop has already been stressed, especially at higher altitudes and latitudes, and so the potential grower should certainly seek ADAS advice before embarking on their cultivation.

Any comments or suggestions should be referred to the author.

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References

Beck, H, 1977. Days of last spring and first autumn air frost in the United Kingdom and runs of days with air frost. Agricultural Memorandum No 815.

Gloyne, R.W., 1971. A note on the average annual mean of daily earth temperature in the United Kingdom. The Meteorological Magazine, 1182, pp 1-6.

Gray, D, Steckal, J.R.A, and Ward, J.A, 1979. The effects of fluid sowing pre-germinated seeds and transplanting on emergence, growth and yield of outdoor bush tomatoes. (In publication)

Gray, D, Steckal, J.R.A, and Ward, J.A, 1979. A comparison of methods of growing tomato transplants. (In publication)

Green, F.H.W, and Harding, R.J, 1979. The effect of altitude on soil temperature. The Meteorological Magazine, 1280, pp 81-91.

Harding, R.J, 1979. Altitudinal gradients of temperature in the Northern Pennines. Weather, Vol 34 No 5, pp 190-202.

Hough, M.N, 1978. Mapping areas of Britain suitable for maize on the basis of Ontario Units. ADAS Quarterly Review, 31, pp 217-221.

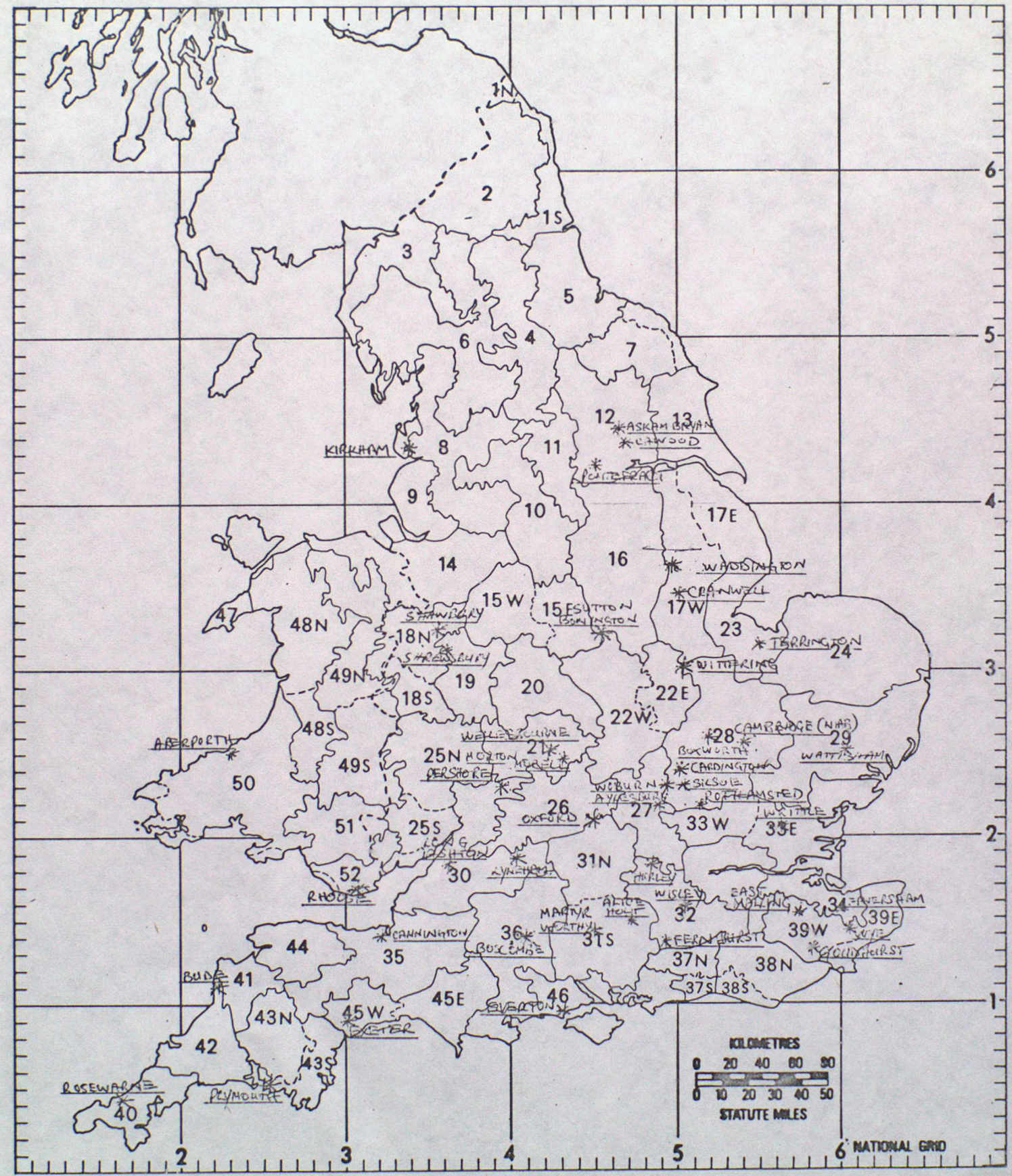
Meteorological Office, 1976. Averages of temperature for the United Kingdom. Met O 833.

Smith, L.P, 1950. Variations of mean air temperature and hours of sunshine on the weather slope of a hill. The Meteorological Magazine, 938, pp 231-233.

Smith, L.P, 1976. MAFF Technical Bulletin 35, The agricultural climate of England and Wales.

FIG 1.

'DAILY' STATIONS USED IN THE ANALYSIS.



AGROCLIMATIC AREAS FOR ENGLAND AND WALES

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FIG. 2

STATION	HEIGHT ABOVE SEA LEVEL (M)	LATITUDE (DEGREES)	Period 1/5–30/9* MEAN TEMP °C	Period 1/5–30/9* HEAT UNITS	Period 15/5–30/9* MEAN TEMP °C	Period 15/5–30/9* HEAT UNITS
HURLEY	43	51.53	14.506	2465	14.844	2322
MARTYR WORTHY	84	51.10	14.243	2401	14.592	2266
GOUDHURST	85	51.07	14.205	2398	14.538	2261
EVERTON	16	50.73	14.562	2493	14.933	2363
WISLEY	32	51.28	14.820	2546	15.150	2395
EAST MALLING	39	51.28	14.642	2510	14.938	2364
FAVERSHAM	48	51.28	14.519	2476	14.856	2335
ALICE HOLT LG	115	51.18	14.237	2395	14.586	2263
FERNHURST	57	51.03	14.204	2398	14.570	2265
AYLESBURY	96	51.78	14.332	2420	14.664	2281
OXFORD	63	51.77	14.974	2587	15.303	2433
LYNEHAM	145	51.50	14.033	2330	14.376	2208
CARDINGTON	29	52.10	14.271	2413	14.595	2269
SUTTON BONINGTON	48	52.83	13.915	2314	14.232	2183
CRANWELL	62	53.03	13.967	2316	14.310	2190
ROTHAMSTED	128	51.80	14.073	2345	14.401	2213
WOBURN	89	52.02	14.004	2338	14.325	2204
SILSOE	59	52.02	14.209	2391	14.533	2252
WITTERING	73	52.62	14.317	2407	14.647	2271
WADDINGTON	68	53.17	14.059	2337	14.398	2210
CAWOOD	6	53.83	13.680	2253	14.003	2130
ASILAM BRYAN	33	53.94	13.753	2270	14.096	2149
PONTEFRACT	78	53.70	13.832	2278	14.190	2162
POSEWARNE	76	50.22	14.099	2359	14.447	2243
EXETER	32	50.73	14.533	2493	14.892	2357
PLYMOUTH	27	50.34	14.411	2449	14.777	2327
CANNINGTON	28	51.15	14.722	2534	15.076	2394
LONG ASHTON	51	51.43	14.547	2482	14.888	2340
PERSHORE COL.	40	52.10	14.696	2521	15.055	2381
RHOOSE	67	51.40	14.186	2387	14.544	2264
ABERPORTH	133	52.13	13.371	2125	13.714	2031
WELLESBOURNE	47	52.20	14.152	2379	14.489	2241
MORTON MORELL	85	52.20	14.178	2380	14.511	2245
TERRINTON	3	52.75	14.229	2389	14.547	2251
BOXWORTH	48	52.25	14.385	2434	14.690	2306
KIRKHAM	24	53.80	13.502	2205	13.839	2086
SHREWSBURY	55	52.72	14.147	2378	14.477	2245
SHAWBURY	72	52.80	13.655	2255	13.987	2131
WYE	56	51.18	14.489	2469	14.820	2329
BOSCOMBE DOWN	126	51.17	14.275	2404	14.629	2274
WRITTLE	35	51.73	14.489	2471	14.823	2326
CAMBRIDGE (NIAB)	24	52.22	14.714	2516	15.035	2365
WATTISHAM	89	52.12	14.175	2385	14.532	2248
BUDE	15	50.83	14.145	2378	14.479	2252

* AVERAGES 1959–77

MEAN TEMPERATURES (1/5-30/9) REDUCED TO SEA-LEVEL AT 0·6°/100 m. FIG. 3.

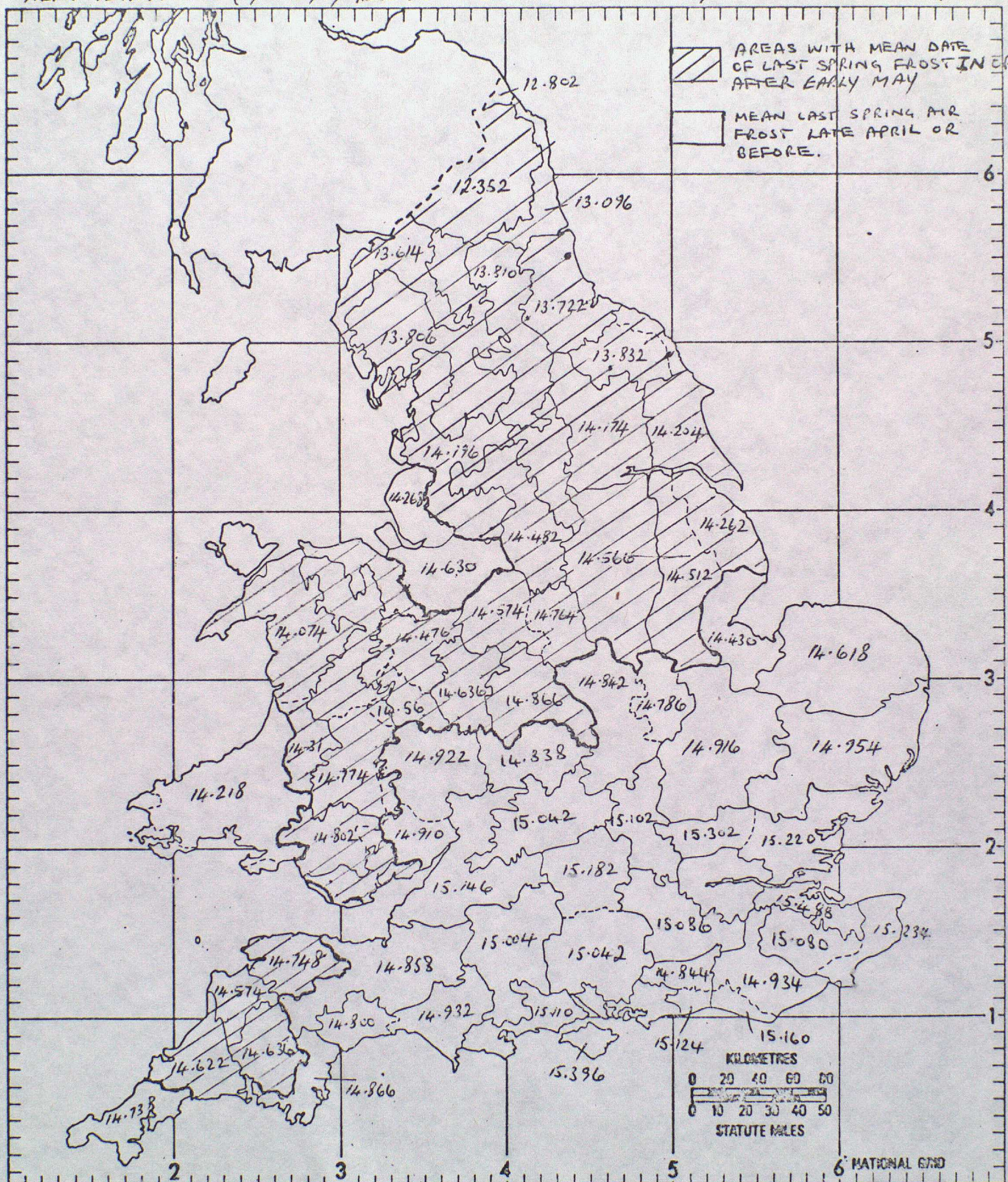

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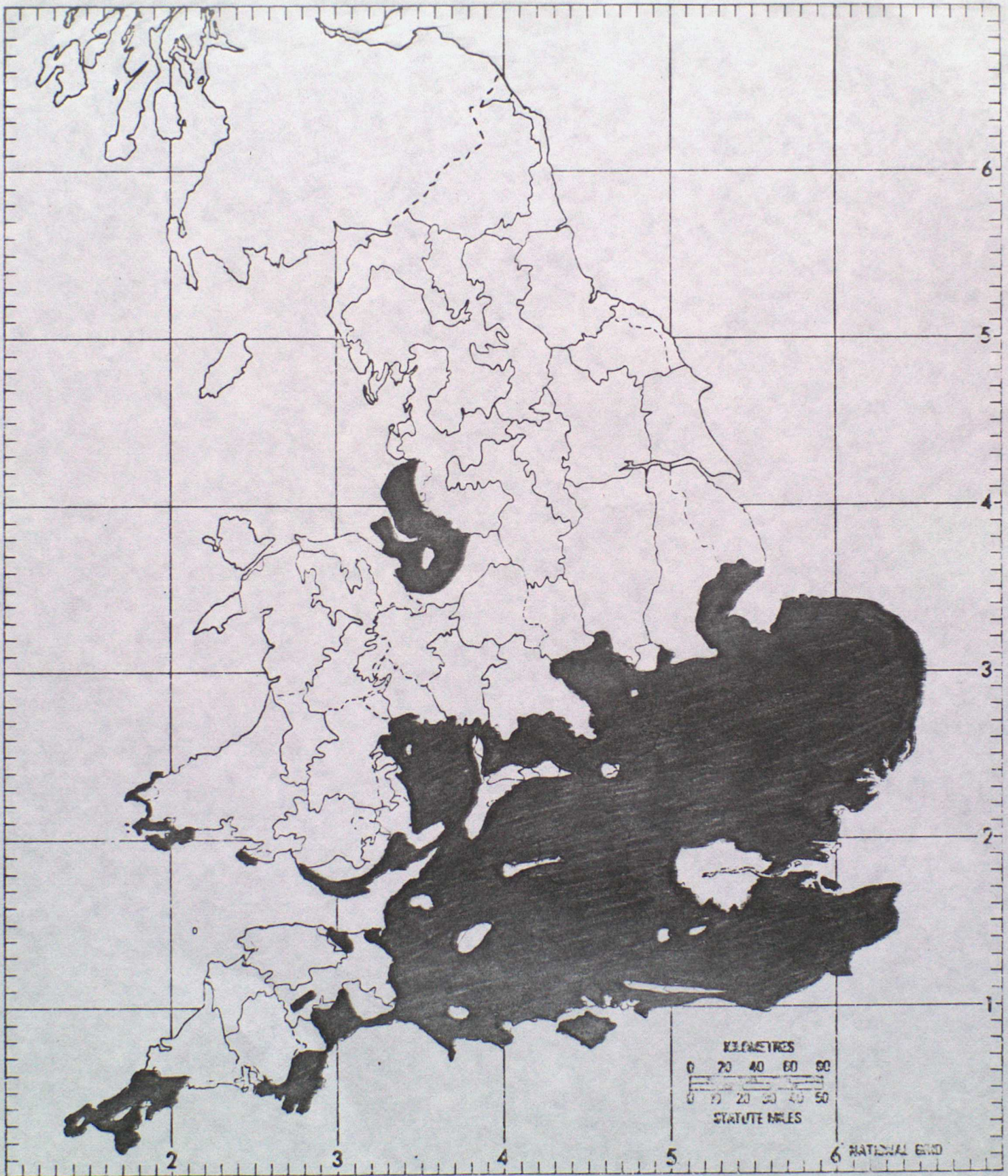
Fig. 4

AGRO-CLIMATIC AREA	MEAN AREA HEIGHT (M)	MEAN TEMP* °C	MEAN TEMP+ °C	MEAN LAST FROST	MAX. HEIGHTS (M) FOR TARGET YIELD			
					SOWING		PLANTING	
					To 37.5 t/ha 9 yrs in 10	To 37.5 t/ha 8 yrs in 10	To 37.5 t/ha 9 yrs in 10	To 50 t/ha 9 yrs in 10
9	28	14.10	14.268	LATE APRIL			71	
14	65	14.24	14.630	"			132	
21	83	14.34	14.838	"			166	
22W	117	14.14	14.842	"			167	
22E	81	14.30	14.786	"			158	
23	5	14.40	14.430	"			98	
24	33	14.42	14.618	"			130	
25N	117	14.22	14.922	"			180	39
25S	105	14.28	14.910	"		3	178	37
26	137	14.22	15.042	"			200	59
27	107	14.46	15.102	"			210	69
28	56	14.58	14.916	"			179	38
29	49	14.66	14.954	"		10	186	45
30	91	14.60	15.146	"		42	218	77
31N	107	14.54	15.182	"		48	224	83
31S	107	14.40	15.042	"			200	59
32	81	14.60	15.086	"		32	208	67
33W	97	14.72	15.302	"		68	244	103
33E	40	14.98	15.220	"		54	230	89
34	58	15.14	15.488	"	44	99	275	134
35	103	14.24	14.858	"			170	29
36	124	14.26	15.004	"			194	53
37N	64	14.46	14.844	"			167	26
37S	64	14.74	15.124	"		38	214	73
38N	79	14.46	14.934	"		7	182	41
38S	70	14.74	15.160	"		44	220	79
39W	80	14.60	15.080	"			207	66
39E	49	14.94	15.234	"	2	57	232	91
40	83	14.24	14.738	EARLY APRIL			150	9
43S	81	14.38	14.866	MID APRIL			171	30
45W	110	14.14	14.800	LATE APRIL			160	19
45E	102	14.32	14.932	"		6	182	41
46	45	14.84	15.110	"		36	212	71
50	123	13.48	14.218	"			63	
52	103	14.38	14.998	MID APRIL		16	191	52
ISLE OF WIGHT	56	15.06	15.396	LATE APRIL	29	84	259	118

+ CALCULATED VALUE AT MEAN SEA LEVEL (1/5 - 30/9)

* AT MEAN AREA HEIGHT (1/5 - 30/9)

PLANTING TO 37½ TONNES/HECTARE 9 YRS. IN 10 – FIG 5



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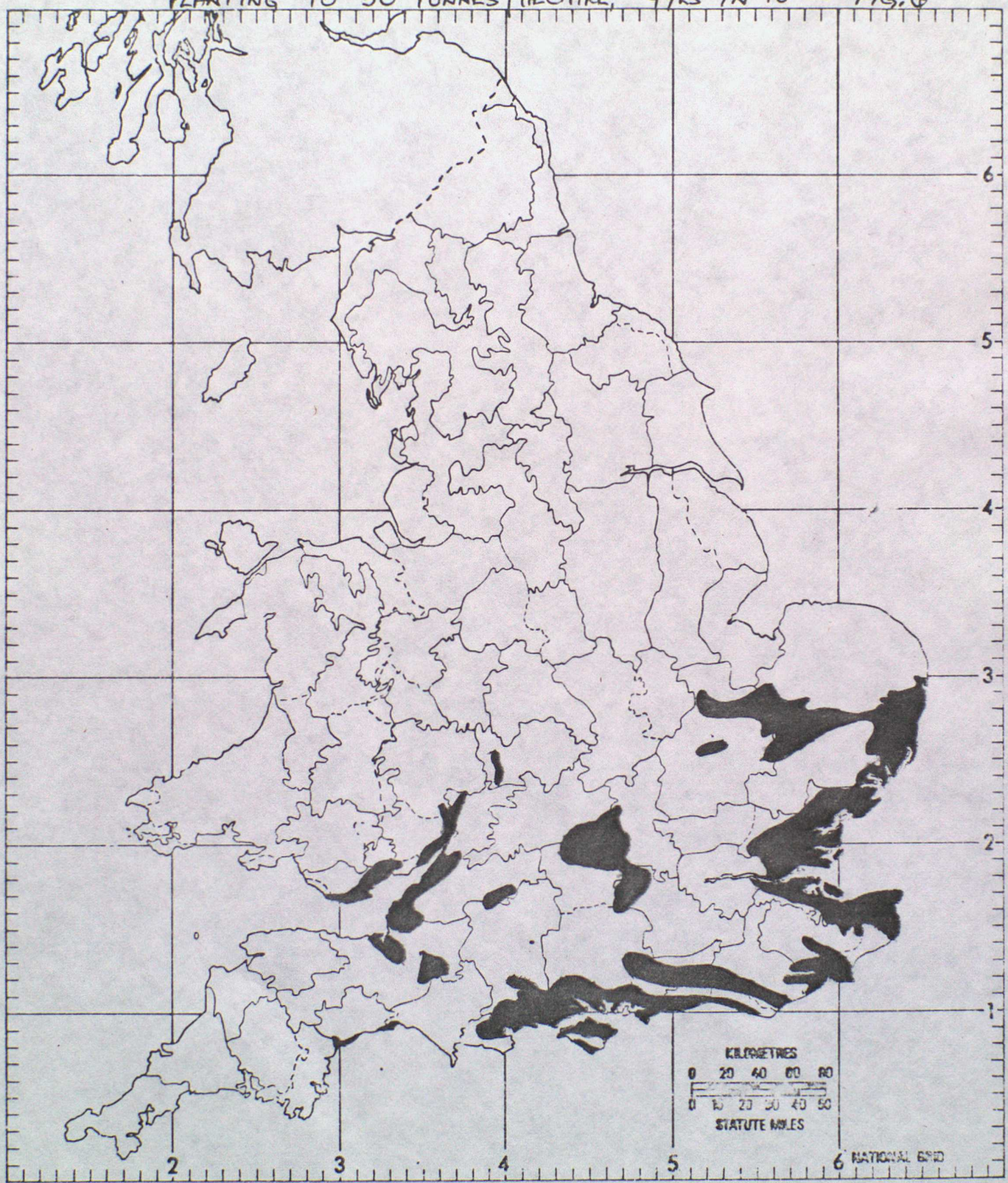
PLANTING TO 50 TONNES / HECTARE, 9 YRS IN 10 — FIG. 6



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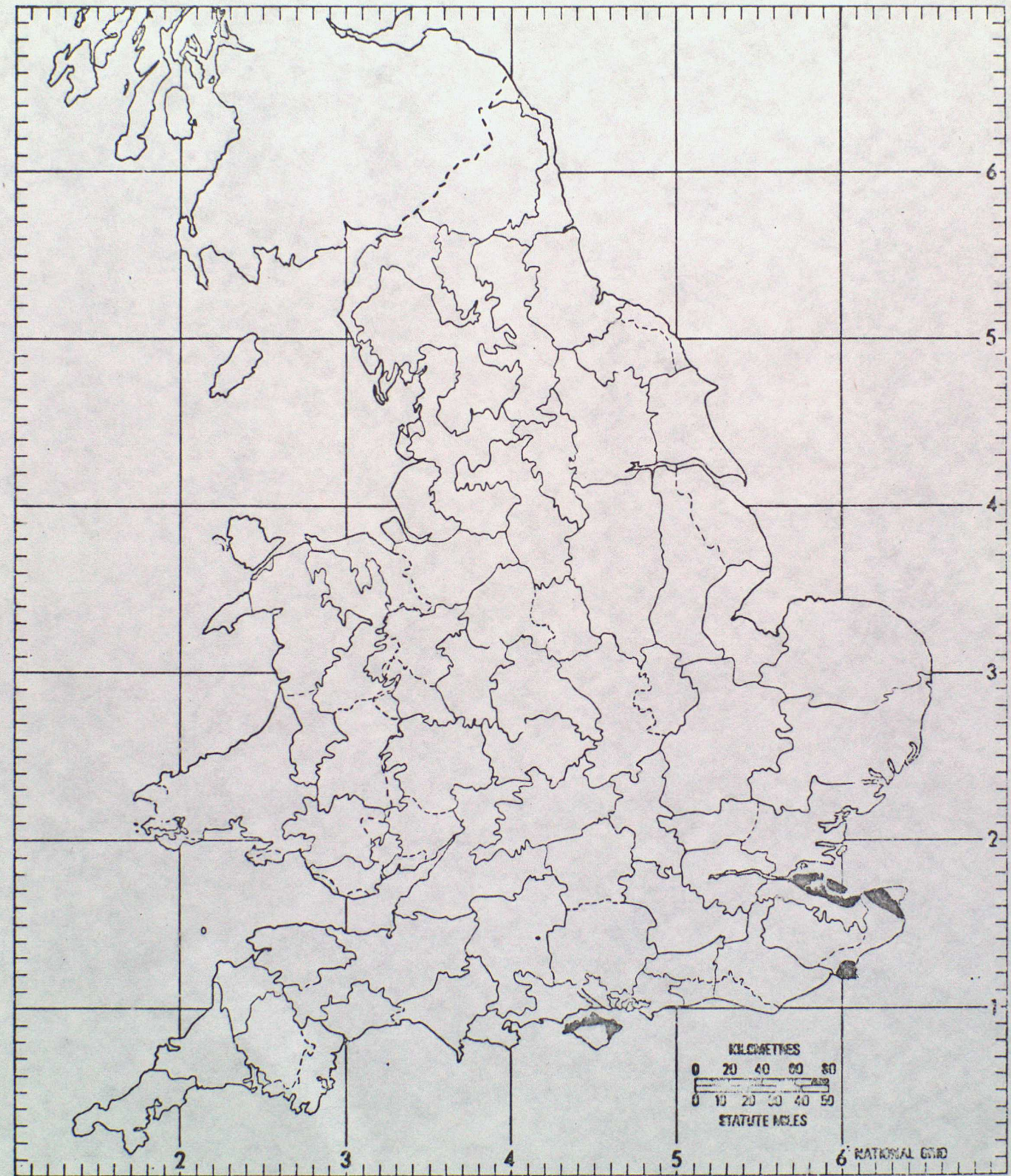
SOWING TO 37½ TONNES/HECTARE 9 YRS. IN 10 – FIG. 7



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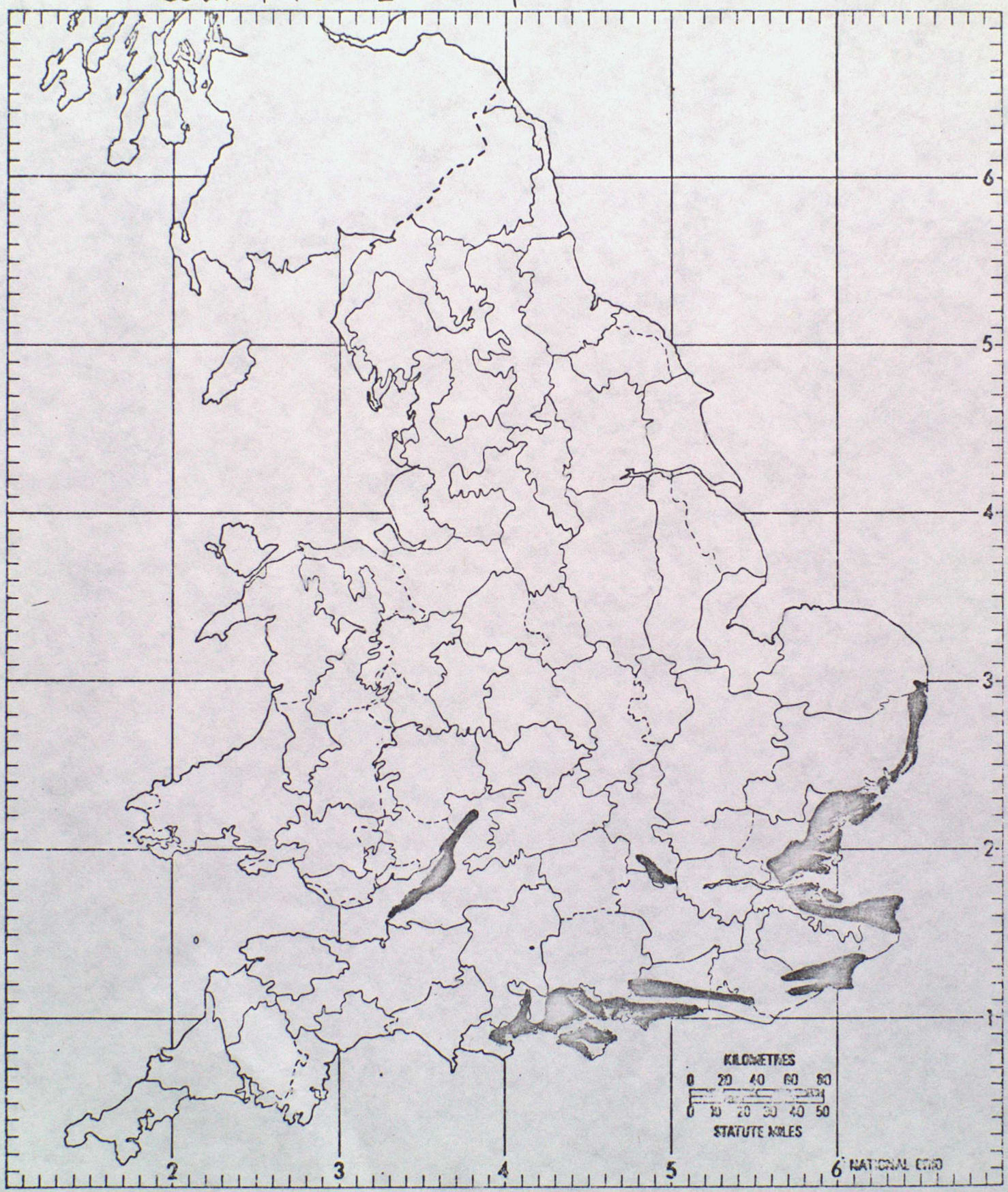
SOWING TO 37½ TONNES/HECTARE 8 YRS. IN 10 – FIG. 8



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